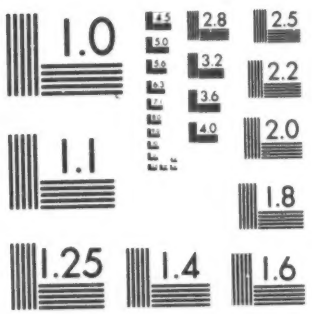

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DOCUMENT RESUME

ED 175 459 IR 007 628

AUTHOR Fennell, Joseph P.; And Others
TITLE Projection for the Future of Instructional Computing in the Montgomery County Public Schools.
INSTITUTION Montgomery County Public Schools, Rockville, Md.
SPONS AGENCY Human Resources Research Organization, Alexandria, Va.
REPORT NO HumRRO Report No. FR-ED-77-3
PUB DATE Feb 77
NOTE 42p.

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Computer Assisted Instruction; *Computer Managed Instruction; Computer Science Education; Costs; *Educational Technology; Elementary Secondary Education; Prediction; *Program Evaluation

ABSTRACT

This report summarizes the findings of a one man-month study of the current status and future direction of instructional computing in the Montgomery County, Maryland, Public Schools including computer assisted instruction, computer managed instruction, computer assisted problem solving, and data processing education. The report is presented in six sections: (1) the approach--a description of the methods used for gathering information; (2) current status of instructional computing in the MCPS system--brief descriptions of the present deployment and use of computer terminals in the schools and the Learner-Centered Management Support System (LCMSS); (3) the future of instructional computing in MCPS--a five year projection for instructional computing and questions about the validity of such predictions; (4) a descriptive analysis of the MCPS computer system; (5) possible future developments in instructional computing, investigating alternatives for expansion and relating costs for these alternative methods; and (6) recommendations summarizing the major findings of the study. (Author/RAO)

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ED175459

PROJECTION FOR THE FUTURE OF INSTRUCTIONAL COMPUTING IN THE MONTGOMERY COUNTY PUBLIC SCHOOLS

Prepared for

Montgomery County Public Schools
Rockville, Maryland

by

Joseph P. Fennell
William G. Underhill
Carol Hargan

Robert J. Seidel
Principal Investigator

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Human Resources Research Organization
300 North Washington Street
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February 1977

IR001628

FOREWORD

This study was performed in HumRRO's Eastern Division where Dr. J. Daniel Lyons is the Director. Dr. Robert J. Seidel is the Principal Investigator for the project.

We appreciate the time, conscientious response to requests for data, and candid opinions of the Montgomery County Public Schools personnel who helped us during this study.

PROJECTIONS FOR THE FUTURE OF INSTRUCTIONAL COMPUTING IN THE MONTGOMERY COUNTY PUBLIC SCHOOLS

INTRODUCTION

This report summarizes the findings of a one man-month study of the current status and future direction of instructional computing in the Montgomery County Public Schools. By instructional computing we refer to:

1) computer assisted instruction (CAI) - interactive tutorials and drills delivered to students via computer
2) computer managed instruction (CMI) - using the computer to monitor and prescribe instruction in an individualized curriculum
3) problem solving - using the computer as a laboratory tool in various disciplines (e.g., physics, social sciences) to enhance learning
4) data processing education - instruction about computers; uses, programming languages, operations.

The authors of this report were expected to assemble and analyze data pertaining to present and projected instructional applications of computing for MCPS. The time allocated for the study permitted only limited penetration and coverage. Nevertheless, some observations are possible which we believe will be helpful and supportive, as well as indicative of potentially serious problems.

The report is organized as follows:

- APPROACH a description of the methods used for gathering information

- CURRENT STATUS OF INSTRUCTIONAL COMPUTING IN MCPS

  This section contains a brief description of the present deployment and use of computer terminals in the schools and a description of the current state of the new LCMSS development.

- FUTURE OF INSTRUCTIONAL COMPUTING IN MCPS

  Here we present five year projections made by MCPS personnel which will result in a 790 terminal system for various forms of instructional computing. We then raise questions concerning the validity of these projections in the face of certain unresolved policy issues for instructional computing.

- DESCRIPTIVE ANALYSIS OF THE MCPS COMPUTER SYSTEM

  This section draws upon computer utilization statistics for the DMICS 370/158 in order to examine the type and amount of computer resources required by the current instructional software at MCPS. The current configuration is found to have significant excess capacity. An upperbound on the number of simulataneous terminal users for the current system is developed (≈ 200 terminals).

- POSSIBILITIES FOR FUTURE DEVELOPMENT OF INSTRUCTIONAL COMPUTING BY DMICS

  Here we present some alternatives for expansion of DMICS instructional support in the future. We also derive unit costs for each alternative for comparison purposes.

- RECOMMENDATIONS AND CONCLUSIONS

  This section summarizes our major findings and suggests areas which require further study.

- BIBLIOGRAPHY

APPROACH

This study was conducted in six steps. They were to:

1) Gather information on the present state of instructional computing in the Montgomery County Public Schools (MCPS);
2) gather information on plans for the future of instructional computing;
3) produce an interim description of 1 and 2 above, including a list of unresolved questions and policy decisions pertinent to the computer support required for instruction over the next five years and beyond;
4) characterize the hardware, software and operations of the computer system currently used to support instruction at MCPS;
5) describe alternative computer configurations which might be considered for future use; and
6) produce a report stating the findings of the study.

Information was collected primarily by interviewing MCPS personnel and by studying documentation on the current computer system, descriptions of instructional applications and samples of the reports produced by the system. The information for step 1 above was gathered through a series of interviews with Ms. Catherine Morgan, Ms. Beverly Sangston, math specialists, teachers and aides. We attended feedback sessions at both ISM and MIS schools to learn more about the teachers' reactions to computer-managed assessment and reports. Dr. Stuart Milner of Catholic University, a consultant to the project, was interviewed concerning his extensive experience in the management of instruction both with and without a computer.

We discussed future plans for computer support of instruction with the following MCPS personnel: Dr. Robert O'Reilly, Mr. William Martin, Dr. Lois Martin, Ms. Catherine Morgan, Ms. Beverly Sangston and Mr. Joseph Martina.

Our view of the county's five-year plan for LCMSS and a list of questions were written in an interim report. Subsequent meetings with MCPS personnel led to the conclusion that answers to many of these questions are currently unavailable.

Mr. Fennell concentrated on collecting data concerning the IBM 370/158, its present operation, and its capacity to support projected needs. These statistics were available either from Mr. Martin or from documents and reports produced by the Department of Management Information and Computer Services.

CURRENT STATUS OF INSTRUCTIONAL COMPUTING IN MONTGOMERY COUNTY PUBLIC SCHOOLS

There are approximately 88 computer terminals in the Montgomery County Public Schools being used for instructional purposes. About 8% of these terminals are being used to support the mathematics component of the Learner-Centered Management Support System (LCMSS). The remaining terminals are being used for computer-assisted instruction (CAI), computer-managed geometry courses, the secondary school remote computing project and a National Science Foundation sponsored project in science (SCAT).

The following is a summary of these activities. All are currently supported on the IBM 370/158.

	No. Schools	No. Terminals/School	Purpose
Secondary Schools:	12	1 - 2	Remote Computing Project
	4	4 - 6	CAI, CMI, Geometry
Junior High and Elementary:	2	4, 10	CAI
	7	4 - 6	CAI and ISM (1 SCAT, 1 first grade CMI with audio)
	3	1	SCAT
	8	0	MIS
Special Education:	2	1	CAI

Although requiring only a small percentage of instructional computer use at present, LCMSS has a projected growth far in excess of the other current uses of a computer in instruction. Therefore, this report will concentrate on the computing requirements of LCMSS, both now and in the future.

The five-year plan for the development and implementation of LCMSS implies the use of instructional computing in the curricula for mathematics, science, social studies and reading and language arts. Mathematics is the first discipline area in which a system (ISM) has been developed and piloted.

ISM/MIS is now operational in 15 schools, 12 elementary and 3 junior high schools. Seven of these schools are "computer" schools (ISM); the remaining are "pencil and paper" (MIS). A total of 7,627 students are registered in the math system. Two hundred and two teachers participate with a total of 274 math sections or classes.

Key objectives in 26 categories have been identified for grades K-8. There is an average of 30 key objectives that a student "should" master each year. A student is assessed on an objective approximately one time each week. Each assessment lasts 5-10 minutes. Each ISM school requires a half-time aide to assist the assessment process for demonstration items and for assessment of pre-literate students. Each MIS school requires a full-time aide. At the computer schools all assessment is done on-line except for "demonstration items." Reports are run every two weeks and delivered to each school by pony. At "paper and pencil" schools, the pony delivers test results to the Central Office every 2 weeks. Data are entered that day. Reports are generated that evening and returned to a school the following day by pony.

Three reports are generated by the system.

Report	Audience	Frequency	No. Generated/Year
Student Profile	Teacher	3/year/student (except K-1)	21,000
Class Profile per Category	Teacher	Every two weeks	10,000
Monthly Report	Principal Teacher	Each month	2,200
		Approximate TOTAL	33,000

Turnaround time ranges from 2 weeks to 3 days, depending on when assessment last occurred. In general, there does not seem to be any dissatisfaction with this schedule among teachers or the ISM/MIS staff.

A report on the percentages of students at, above, and below grade level is being developed to help with curriculum revision. Cumulative reports (e.g., by grade level, by area) will be developed for MCPS decision makers.

THE FUTURE OF INSTRUCTIONAL COMPUTING IN MONTGOMERY COUNTY PUBLIC SCHOOLS

Montgomery County Public Schools projections for the next five years indicate growth in all instructional computing activities with the exception of CAI/CMI for secondary school students. Figure 1 is a chart prepared by Mr. Martina, of DMICS, describing the projected growth in five categories of instructional computing; CAI and assessment, CAI only, computer assessment only, CAI/CMI and remote computing.[1] The chart shows the total number of terminals in each instructional computing category that is projected for each type of school over the next five years. Another chart is available which projects the same total growth but over a ten-year period.

The chart shows that all senior high schools are scheduled to be a part of the remote computing project by FY 1978. No further growth in this area is indicated for the next five years. Schools which have only CAI at present will also begin to use computer supported assessment. As new schools become involved in computing, they will acquire terminals for assessment during their first year of participation. In their second and following years they will have CAI as well as computer supported assessment. Over the next five years, the percentage of the total number of terminals in the schools being used for management and assessment will increase from the current 8% to well over 50%.

ISM will be expanded to an additional 15 schools next year, bringing the total to 30. This is the number of schools chosen for a summative evaluation of ISM.

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[1] This chart is a draft. The totals are essentially accurate although the exact figures for deployment of terminals have been modified.

		CAI-CSA		CSA		CAI		CAM-CMI		GLPPS		TOTALS	
FY	TYPE SCHOOL	# SCH	# TERM	# SCH	# TERM	# SCH	# TERM	# SCH	# TERM	# SCH	# TERM	# SCH	# TERM
	Elementary	6	27	–	–	1	4	1	4	–	–	8	35
	Middle	–	–	–	–	1	10	–	–	–	–	1	10
77	Junior	–	–	1	4	–	–	–	–	–	–	1	4
	Senior	–	–	–	–	–	–	4	20	11	17	15	37
	Special	–	–	–	–	2	2	–	–	–	–	2	2
77	TOTALS	6	27	1	4	4	16	5	24	11	17	27	88
	Elementary	12	55	5	10	1	4	1	4	–	–	19	73
	Middle	–	–	–	–	1	4	–	–	–	–	1	4
78	Junior	3	24	1	4	–	–	–	–	–	–	4	28
	Senior	–	–	–	–	–	–	4	20	22	44	22	64
	Special	–	–	–	–	2	2	–	–	–	–	2	2
78	TOTALS	15	79	6	14	4	10	5	24	22	44	48	171
	Elementary	19	7[illegible]	35	70	–	–	–	–	–	–	54	143
	Middle	1	8	1	4	–	–	–	–	–	–	2	12
79	Junior	4	32	7	28	–	–	–	–	–	–	11	60
	Senior	–	–	–	–	–	–	4	20	22	44	22	64
	Special	2	2	–	–	1	1	–	–	–	–	3	3
79	TOTALS	26	115	43	102	1	1	4	20	22	44	92	282
	Elementary	54	213	35	70	–	–	–	–	–	–	89	283
	Middle	2	16	1	4	–	–	–	–	–	–	3	20
80	Junior	11	88	7	28	–	–	–	–	–	–	18	116
	Senior	–	–	–	–	–	–	4	20	22	44	22	64
	Special	3	3	–	–	1	1	–	–	–	–	4	4
80	TOTALS	70	320	43	102	1	1	4	20	22	44	136	487
	Elementary	89	353	36	72	–	–	–	–	–	–	125	425
	Middle	3	24	–	–	–	–	–	–	–	–	3	24
81	Junior	18	144	7	28	–	–	–	–	–	–	25	172
	Senior	–	–	–	–	–	–	4	20	22	44	22	64
	Special	4	4	–	–	1	1	–	–	–	–	5	5
81	TOTALS	114	525	43	100	1	1	4	20	22	44	180	69
	Elementary	125	497	–	–	–	–	–	–	–	–	125	49
	Middle	3	24	–	–	–	–	–	–	–	–	3	24
82	Junior	25	200	–	–	–	–	–	–	–	–	25	200
	Senior	–	–	–	–	–	–	4	20	22	44	22	64
	Special	5	5	–	–	–	–	–	–	–	–	5	5
82	TOTALS	158	726	–	–	–	–	4	20	22	44	180	790

Figure 1. Five-Year Projections for Terminals in MCPS

Nine of the 15 new schools will also begin using computer terminals for CAI in 1977-78. The remote computing project will be expanded from 12 high schools to 22. This will require leasing or purchasing 27 new (or used) teletype terminals. The total number of terminals projected to be leased or purchased during the coming year is, therefore, 83. Recommendations about this acquisition will be discussed in a further section of the report.

A mini-computer will be installed in 1977-78 for the reading area of LCMSS. This mini-computer will be used for readability analysis, comprehensive achievement monitoring (CAM), and development of an instructional resource index. There is also a large committee under the direction of Ms. Morgan whose purpose is to develop a conceptual framework for a reading/language arts instructional system including objectives, teaching and learning strategies and assessment procedures.

If the five-year plan is followed, all Montgomery County elementary and junior high school students will be following mathematics, reading, language arts, science and social studies curricula supported by LCMSS in 1982. County enrollment is projected to decrease by 1982 with approximately 14 fewer elementary schools for a total of ≈ 125 and 4 fewer junior high schools for a total of ≈ 28. Figure 2 shows CAI and assessment activities requiring ≈ 726 terminals by 1982. Secondary school activities bring the total number of terminals to 790.

According to the following calculations, this total appears to be the minumum number of terminals required to support both CAI and assessment.

Each ISM elementary school (≈ 500 students) now has one terminal devoted to math assessments. Calculations show that if each student in grades 2-6 (≈ 360 students) is tested for 5 minutes each week, the terminal would be operating a minimum of 30 hours each week, or 6 hours each day. Such a schedule

would be difficult to maintain due to such things as equipment failures, school assemblies and queueing problems. The ISM junior high school uses 3-4 terminals for math assessments.

Montgomery County Public Schools staff project that 2 1/2 times the number of terminals necessary to support ISM will be required for all the discipline areas under LCMSS. The rationale for this is that fewer students (e.g., 3-8 rather than K-8) will be assessed in science and social studies with fewer of these assessments being done by terminal. Therefore, approximately 310 (2 1/2 x 125 schools) terminals will be required to support LCMSS for elementary students.[1] The 28 middle and junior high schools will require = 224 terminals for LCMSS for a grand total of 534 terminals dedicated to assessment.

Montgomery County Public Schools staff have described the "ideal" elementary school as having three terminals devoted to CAI, primarily for math in grades 3-4. To accomplish this goal, an additional 375 terminals would be required for elementary schools. This plus the five terminals used in special education brings the total number of terminals for CAI and assessment in all types of schools, except secondary, to a total of 914. Adding the 64 secondary school terminals brings the grand total to 978. The following table shows a discrepancy between Figure 1 and these calculations.

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[1]Since 2 1/2 terminals/school is not possible, the figure could be rounded up or down, or terminals could be placed in schools according to enrollment.

# Terminals Calculated in this Report			# Terminals from Figure 1
CAI	375	} 685	} 497
Assessment	310		
Middle/Jr. High	224		224
Special	5		5
Subtotal	914		726
Senior	64		64
Total	978		790

In other words, if the plan is to actually have 726 terminals for CAI and assessment, it will be necessary to reduce the amount of terminal time that has been described as ideal for CAI. This gives rise to the question of what amount of CAI is required in order to be effective for the target population (grades 3-4).

Current computer usage statistics show only ≈ 40% of the 88 terminals in the schools being used at any one time during peak hours and an average of 25% on the terminals being used at any one time during the 11 hours schools are open. As LCMSS becomes operational in all discipline areas, the peak load will almost certainly increase from 40% to close to 100% of the 726 terminals using the computer during school hours.

The previous description concentrated on the number of terminals which would be required to support instruction in MCFS over the next 5-10 years. There are other computer resources such as central processing cycles, data storage space, and volume of printed output which should also be analyzed in terms of future requirements. Because of the evolving nature of LCMSS, its computer support requirements in these areas are unknown at present. The following issues must be resolved before such requirements can be formulated.

The frequency, duration, and complexity of computer-based assessments is not yet defined for LCMSS discipline areas other than mathematics (ISM). Indeed, the current form of assessment in ISM may be changed as a result of the summative evaluation in progress. In addition, there is as yet no decision on whether or not to include retention tests and pre-tests in LCMSS.

The size, frequency of generation and audience size of each type of LCMSS report has not yet been defined. Decisions in this area affect both the volume of computer generated output and the amount of intermediate computer data items which must be retained on each student

Until decisions have been made about the questions raised above, it will be impossible to project accurately the required number of terminals, amount of computation, volume of printed output and amount of peripheral data storage needed to support assessments and reporting.

The projections for the number of terminals in the schools could also be radically changed by increasing the amount of instruction about computers in secondary and vocational schools. Although computer science is a relatively new discipline, more and more school systems throughout the country, including almost all in the District of Columbia metropolitan area, are expanding their curricula to include computer programming and data processing. In addition, computers are becoming common as problem-solving tools in other discipline areas such as chemistry, physics, biology, social science, and mathematics. Whereas the MCPS projections show 44 terminals in 1982 in the secondary schools for problem solving and learning computer programming, this figure is only ≈ 20% of the number of terminals now available for these purposes in Prince George's County high schools. The District of Columbia Public School System today has four computers and approximately 60 terminals in its high schools for instructional purposes.

The limited availability of computing for secondary students should be a critical concern if Montgomery County is to continue to be a leader in providing relevant instruction for its students. Recommendations for providing such instruction in a cost-effective manner are discussed later in this report.

DESCRIPTIVE ANALYSIS OF THE MONTGOMERY COUNTY PUBLIC SCHOOLS COMPUTER SYSTEM

Some reasonable detailed understanding of the present management of computing at MCPS, and of the implications of that arrangement, is needed in order to develop perspective concerning possible paths for development. For a baseline we draw upon the data shown in Tables 1, 2 and 3.

Table 1 contains utilization statistics provided by DMICS. These data pertain to the month of December 1976 and are believed to be adequately representative of activity during the fall and spring school sessions. The entries are obtained through analysis of System Management Facility (SMF) records—a common and useful practice in computer centers using IBM systems. Computer utilization is, here, described in terms of the subsystems which are listed in the left-hand column of the table. The entries in this table are percentages of the totals (actual units shown in the bottom line).

Table 2 contains CAI system statistics provided by the COURSEWRITER III monitor. These statistics are averages obtained from sample data for a recent period (16 sample days for which the school session appears to be normal--day-to-day variation within the sample was not pronounced).

Table 3 contains utilization data for the central system in use at The George Washington University, an IBM 370/145 (OS/VSI).

Table 1. Resource Utilization by Subsystem (DMICS/December 1976)

Subsystem	DISC I/O	TAPE I/O	TIO[2]	PRINTING	CPU
(1)	6.9%	8.4%	1.4%	2.2%	2.6%
+CAI/CMI	18.0	2.5	82.5	1.9	34.9
Local Admin.[3]	1.3	1.3	3.0	2.5	1.4
*Financial Systems	8.9	14.8	-	14.1	7.7
IT (CALL-OS)	1.2	-	12.5	-	4.3
*Material/Warehousing	2.0	7.5	-	1.1	2.9
*Personnel Systems	28.8	23.4	-	26.5	15.8
*Pupil Systems	9.3	14.7	-	11.4	10.5
*Applic. Dev.	18.2	10.4	-	31.2	14.3
Systems Environment	3.7	7.8	-	2.6	2.5
RJE (Blair H.S.)	-	-	-	-	-
Miscellaneous	1.2	9.2	-	5.1	2.4
Other[4]	-	negligible	-	-	-
TOTAL (percent)	99.5	100.0	99.4	98.6	100.0
TOTAL (units)	31.4(M)	13.3(M)	5.1(M)	12.8(M)	134(H)

(1) If named in report.

(2) Teleprocessing transactions

(3) Local (ESC) use of terminals (CICS)

(4) IBM, "JOB" and a small research project

(M) millions

(H) hours

* + used below in reference

Table 2. CAI System Statistics[1] December/January 1976/77

Sample Period (hours)	Percent of CPU	Response[2] Rating	Entries[3]	# Users
9.5	30	98	37600	45

(1) Average based on 16 days experience

(2) Percent of occasions when the system responded in less than 3 seconds

(3) ENTER KEY operations

(4) This appears to be a once-a-day snapshot

Table 3. Resource Utilization by Subsystem (GWU/CAAC, FY 76)

SUBSYSTEM	DISC I/O	TAPEI/O	TIO	PRINTING	CPU
System Environment	9.7	6.9	-	3.8	7.5
Instr/Research	17.4	9.7	-	28.4	57.7
All Admin[1]	72.6	83.4	-	67.8	54.8
TOTAL (percent)	99.7	100.0	-	100.0	100.0
TOTAL (units)	208(M)	104(M)	-	313(M)	2757(H)

(1) Including applications development

(M) millions

(H) hours

Discussion

The computer system operated by DMICS functions in rather distinct ways as an administrative resource and as an instructional resource. With the exception of minor use of CALL-OS (ITF) and exercise of a remote batch terminal at Blair High School, instructional support is provided almost entirely through CAI/CMI (COURSEWRITER III). The following picture emerges from Table 1.

(1)	DISC I/O	TAPE I/O	TIO	PRINTING	CPU
+Instruction (CAI)	18.0	2.5	82.5	1.9	35
*Admin. Applic.(2)	67.2	70.8	-	84.3	51

(1) All entries are percents of totals

(2) (*) and (+) from Table 1.

The annual CPU statistics for GWU (Table 3, from SMF records #4 and #5) indicate that it is possible to exercise System 370 (under OS/VSI) at least 32% (2757/87.60) of the annual wall clock hours (8760 hours). The University equipment is not heavily utilized during the third shift or on weekends, so that a utilization rate of 50% is probably attainable for systems of this class, without unusual configuring or special control of the job queue. An extension of the December utilization statistic for the DMICS equipment yields an annual CPU rate of 1600 hours or 18% (December may be a little light because of Christmas holidays, but this effect would tend to balance out when use during summer months is taken into account). This implies that there is a substantial residual processing resource available to MCPS. As will be seen below, this additional resource is not necessarily directly and simply accessible.

Administrative use at GWU (Table 3) results in about 450 million input/output transactions each year (151M-disc, 87M-type, 212M printer). A direct calculation from Table 1 yields an annual total of 480 million input/output transactions for the DMICS system. In other words, the latter system, exclusive of support for CAI, performs in a way very similar to the administrative system of the University. CPU utilization for the two administrative applications stands at 1044 hours (DMICS, extended) and 1511 hours (University). If the instruction rate for the 370/158 is taken to be three times that of the /145, it would appear that about twice as much CPU activity is required at DMICS for the same amount of "administrative" product. The factor of 3 is reasonably close to that suggested by Grosch's Law when the prices for the two systems are compared. This law states that a computer costing twice as much as another will run about 4 (2 x 2) times as fast. Second order effects in the generation of SMF data and programming practice can be expected to produce variation (indirectly and directly, respectively) in recorded CPU utilization. The effect seen here is much more substantial and appears to thrust directly at the notion of economy of scale as evidenced in System 370. Littrell (19) and (20) provides further information concerning this matter. The question is closely related to issues posed below in the section entitled, Technological Overview.

The prospect of increased use of CAI/CMI in the given environment suggests, very directly, some rather important considerations. From Table 2, CAI now accounts for about 35% of 134 hours of CPU utilization, or 47 hours per month in all. As indicated in Table 2, COURSEWRITER is in use about 10 hours per day. Assuming that there are 22 school days per month, about 220 hours of wall clock time are then available for use of CAI. Under a CPU use rate of 60%, a total of 132 hours (of CPU seconds) in all is available for support of CAI,

effectively limiting deployment of this application to about three times its present level, i.e., to use of about 240 terminals--if no further investment in central systems facilities is contemplated. An attempt to allocate CPU resources in this way would have a very marked effect upon the behavior of other concurrent applciations. It is not at all apparent that deployment at this level is practical.

As indicated above, overall CPU utilization (DMICS) is now about 18% of wall clock time and that a rate of 50% is probably a practical limit, or goal. Looking at this another way, one might ask what opportunities are provided by this extra capacity. It is to be stressed, however, the CPU reserve is a convenient point of entry and not a precise indicator of residual computer capacity. The components of large contemporary systems interact in complicated ways so that, for example, an extended application of a particular species may produce linking at an input/output interface long before processing cycles come into short supply.

POSSIBILITIES FOR FUTURE DEVELOPMENT OF INSTRUCTIONAL COMPUTING BY DMICS

Several avenues for development seem reasonable as subjects for careful investigation by MCPS and DMICS--given the present facilities, and prior to consideration of other media for development such as minicomputers. Some of the more obvious and natural things to be thinking about are as follows.

Straightforward extension of conventional batch service under one or more of the rubrics (*) in Table 1. The constraint here is likely to be design and programming resources. DMICS now spends about $800,000 for analysts and programmers, and about half of these individuals are involved in application maintenance. About a fourth of the remaining staff time goes for system upkeep, leaving (out of a total of 39 persons) about 15 positions available for program design, programming and testing. In addition to direct involvement in technical undertakings, the entire function ($800,000) is subject to various forms of overhead, such as answering questions and making special runs. (It is worth note in passing that, while the figure $800,000 represents an increase of about $130,000 since FY 1974, the total number of available positions has declined slightly since that time.) DMICS seems to be able to thrust at about 10 new applications during a given year (5). Each requires design and programming and, ultimately, the services of a maintenance programmer. Barring the infusion of large additional sums for program development ($200 - $400,000) per year, this process, as it has been conceived at DMICS (and nearly everywhere else) is almost certain to lag behind the needs of the system for information handling services. Pouring money into these forms of development, or holding the funds constant and waiting for service to catch up with the administrative requirement, is probably a questionable strategy--or, at best, a practice which

calls for further examination. Since instruments should be independently considered during any such examination, the use of interactive terminal services for program development and the adoption of some combination of data base, query and data entry facilities (present limited use of CICS by ESC is an example of such an application). Support systems, such as VSPC, CRJE or WYLBUR (for program development) and IMS or CICS (for query, data entry and data base management) tend to make very heavy use of system resources (disc, CPU cycles, real memory) so that a very careful approach is indicated--one which would take both short- and long-term implications into account. In the case of the data base, query and entry systems consultation with prior users is quite advisable--with appropriate emphasis upon such questions as installation cost, maintenance cost, resource cost and user experience. A particularly important question in the DMICS environment concerns the span of application. One would want to distinguish quite clearly between the local application of query and entry technology in the ESC and a system which provides these forms of service at many other administrative sites, e.g., all high schools. Finally, it is apparent that data preparation, in traditional modes, such as keypunching, and information dissemination in traditional mode, such as printing, contribute significantly to the cost of any mass data handling application.

Enhanced problem-solving service. There are two attractive ways for DMICS to move into problem solving in a more significant way--through the use of remote batch entry terminals (card reader/printer stations) and through the use of minicomputers with printing terminals. Some figures relating to the logistics of problem solving are useful here. During the fall and spring peak load periods (approximately from the time of the first class assignment until the

end of the examination period) at The George Washington University about 1500 students submit 50,000 jobs (FORTRAN, WATFIV and WATBOL) through a remote batch station, with turnaround time of a minute or two. Two things are apparent--students require, on the average, about 30 "shots" per semester, or approximately 6 per assignment; secondly, the batch terminal is a mass production instrument, i.e., a single station is physically capable of providing support for, say, 50 students at each of the 23 high schools of the system.

For purposes of discussion and in the practical vein, it seems reasonable to consider problem solving at, say, 20 high schools, using 5 terminal sites and some pony express (once a day) service. The approximate cost of such an arrangement, assuming 12 month leasing, is seen to be as follows:

		Annual
Batch Terminals	12 x 5 @ $900-$1800/mo.	$ 54,000-$108,000
Keypunch Equipment	12 x 20 x 2 @$80	38,400
Station Keepers	5 x 36 @120/wk.	21,600
Pony Express		?
Paper		minor
Telecommunications		?
Central Computer Resource	9 x 5 @300/mo.	18,000
TOTAL ANNUAL		$132,000-$186,000
Cost/Pupil-Semester (50 x 20 x 2)		$ 61 - $ 93

Deploying minicomputers as a base for problem solving is programmatically and, to an extent, technically, much more complicated than is the use of batch terminals. The device is now a logically complete computer system with all of the generality which that implies. A minicomputer, for example, can serve as a device for local batch service, as a remote batch terminal, as a time-sharing machine for local problem solving, as local support for CAI, or as base for

many many practical combinations of these forms of computer support. For purpose of brevity, only three scenarios will be considered. In the first, the system is employed as a regional batch resource, not connected with the central system. Two levels of investment are postulated, $60,000 for a basic batch-oriented capability, and $100,000 for an extended batch capability. The equipment is assumed to be valueless at the end of five years. The prices indicated are based upon quotations by well known vendors.

Case 1		Annual
Batch Mini System	12 x 5 @ $1000-$1700	$ 60,000-$102,000
Maintenance	12 x 5 @ $500-$600	30,000 - 36,000
Keypunch Equipment	12 x 20 x 2 @ $80	38,400
Managers	5 @ $12,000/yr.	60,000
Pony Express		?
Paper/Cards		minor
Telecommunications		none
Central Computer Resource		none
TOTAL ANNUAL		$188,400-$236,400
Cost/PS-Pupil-Semester (50 x 20 x 2)		$ 94 - $118

In the second situation the $100,000 minicomptuer configuration is extended through the addition of 6 KB/CRT terminals for CAI and 6 KB/CRT/PRINTER terminals for use in problem solving. In addition to serving as a base for CAI and local base for problem solving, the system may also be connected for periods during the day or night with the central system and serves then as a remote batch terminal. All items are again appreciated over a five-year period.

Case 2			Annual
(a)	TS Mini System	12 x 5 @ $1700	$102,000
(b)	CAI Terminals	12 x 5 x 6 @ $25	9,000
(c)	PS Terminals	12 x 5 x 6 @ $75	27,000
(d)	Maintenance	12 x 5 @ $900	54,000
(e)	Keypunch Equipment	12 x 15 x 2 @ $80	28,800
(f)	Managers	5 @ $12,000/yr.	60,000
	Pony Express		?
	Paper/Cards		minor
	Telecommunications		minor
	Central Computer Resource		minor
	TOTAL ANNUAL		$280,800
	Cost/PS-Pupil-Semester (50 x 20 x 2)[1]		$ 81
	Cost/CAI-Pupil-Hour (54,000 units)[2]		$ 2.20

(1) (Half of items (a), (b), (f) plus all of (c) and (e))/(1000 students each of two semesters).

(2) (Half of items (a), (d), (f) plus all of (b))/(terminals x systems x hours/day) x days = 6 x 5 x 10 x 180 = 54,000 contact hours).

As a last scenario the mini-system is organized purely as a CAI resource at 5 high schools--no offsite service for problem solving.

Case 3			Annual
	TS Mini System	12 x 5 @ $1700	$102,000
	CAI Terminals	12 x 5 x 12 @ $25	18,000
	Maintenance	12 x 5 @ $900	54,000
	Managers	5 @ $12,000/yr.	60,000
	TOTAL ANNUAL		$234,000
	Cost/CAI-Pupil-Hour (108,000 units)		$ 2.20

It is worth observing in connection with the BATCH TERMINAL system and the systems defined in Case 1 and Case 2 that there is substantial residual batch capability available for local administrative support. In the case of the BATCH TERMINAL system the processing is performed at the central site and by the regional processor in Cases 1 and 2. It is quite apparent that this capability is available in the first situation. In Cases 1 and 2 the evidence emerges from a simple calculation based upon the availability of 300 card-per-minute card readers and 200 line-per-minute printers at the minicomputer sites (as indicated in price). The total card reading and printing capability at the five regional sites is then as follows for a semester of use.

Reading

(300 CPM x 300 minutes/day x 80 days x 5 systems) = 36,000,000 (cards)

Printing

(200 LMP x 300 minutes/day x 80 days x 5 systems) = 24,000,000 (lines)

Student jobs at GWU average 120 cards of input and 310 lines of output. If 1000 students are enrolled each semester in problem solving and if, on the average, they make 30 runs per semester (of about the complexity of those required at the University), the semester loading is as follows.

Reading

(30 runs/semester x 1000 students x 120 cards) = 3,6000,000 (cards)

Printing

(- - - - - - - - x 310 lines) = 9,300,000 (lines)

It is apparent that there is a very noticeable reserve capacity within a 5-hour day, one which can be used for achievement monitoring, assessment, CMI and for general local administrative applications.

The foregoing examples are intended only as illustrative of the possibilities posed by the technology, and of the (numerous) paths open for more refined exploration. An equivalent cost breakdown of the current instructional system follows.

As already indicated, present use of the DMICS 370/158 is balanced almost exclusively upon general administrative support and CAI services. The latter form of service is based upon the IBM 3270 display system. At the service sites this display system consists of a 3271 Control Unit, Model 1 or Model 2, interfacing with from 1 to 32 service devices, which in the case at hand is the 3277 CRT/KEYBOARD (CRT/KB). Device adapters are attached to the 3271 in approximately a ratio of 1 adapter for each 4 service devices. Monthly rental costs for these items of equipment are as follows.

3271 Control Unit (Model 1 or 2 with one adapter)	$ 184 - $201
3277 CRT/KB (480 or 1920 character buffer)	$ 100 - $139
Device Adapter	$ 61

For purposes of discussion, the MCPS display system is considered to consist of 100 stations, 32 of which are organized into 4 clusters of 8, and the remaining 68 into 17 clusters of 4. The monthly costs for the system are then as follows.

CRT/KB	100 @ $120 (avg. from above)	$ 12,000
3271 CU	17 @ $190 (avg. from above)	3,230
3271 CU (1 added adapter)	4 @ $250 (190 + 61)	1,000
TOTAL MONTHLY		$ 16,230
TOTAL ANNUAL		$194,760

(The last figure given above compares well with the FY 76 and FY 77 CAI budgets for Contractual Services--$195,580 and $190,580.)

From Table 2 annual CAI contact hours are in the neighborhood of 81,000 (45 users x 10 hours/day x 180 days) so that the unit cost for terminal apparatus is approximately $2.40. A preliminary sample (every 15 minutes for 1 day) indicates that the average number of terminals in use is considerably smaller than the snapshot average (Table 2), less than 25. The actual unit cost for terminal apparatus may therefore be more like $4.00.

According to Table 1, CAI accounts for about 35% of CPU utilization and about 18% of disc system use. Computer expenses are described under the title of Contractual Services in most MCPS budgets, and it is difficult to thread through to actual resource costs. For this reason, the following approximations will be employed. The least monthly lease for a system 370/158 central processor and 2.0 megabytes of storage (the DMICS system has 1.5 megabytes of storage) is $43,000. Because of the difference in the size of main memory and the reduced monthly charge under long-term lease, a monthly payment of $25,000 will be assumed. Rather arbitrarily, the monthly disc system cost is taken to be $2000 (present total central system costs are about $920,000/year). Extending in order to arrive at annual costs, and dividing as above, the additional unit costs for CPU and disc are seen to be as follows.

CPU (45 users) 0.35 x $360,000/81,000 = $ 1.55

DISC (45 users) 0.18 x $ 24,000/81,000 = $ 0.05

From the above, unit costs for delivery of CAI range from about $4.00 ($2.40 + $1.60) when the average in-use figures is 45 (pupils) to $6.88 ($4.00 + $2.88) when use hovers around 25. It is quite apparent that if terminal use is intensified, e.g., through different scheduling procedures, the unit cost for terminal apparatus declines, while, because of more intensive exercise of the central processor and the disc storage system, the total cost charged to these resources will increase.

RECOMMENDATIONS AND CONCLUSIONS

- A significant increase in the number of simultaneous terminal users on the DMICS 370/158 will require the acquisition of additional hardware (e.g., more main storage, possibly a second processor). A substantial investment in software development may also be required in order to "tune up" the system for the increased workload. We strongly recommend that, before acquiring more computer terminals, a thorough systems analysis should be done in an attempt to develop conclusive mathematical proof that the projected ≈ 800 terminals can be supported with acceptable response time levels on an enhanced 370/158. If this level of terminal support is shown to be possible, the unit cost for instructional computing should be carefully examined and compared with alternative configurations.

- It seems virtually inevitable that MCPS will find it both desirable and necessary to incorporate computer science topics in its secondary school curriculum in the near future. Student use of computers, both as laboratory tools and as a school subject in themselves, is significantly increasing in Washington metropolitan area schools and across the country. We believe that MCPS personnel should examine this trend in order to determine what types of computer systems will be necessary to meet the demand for student computing resources. We feel that the MCPS projection of two terminals for each senior high school during the next five years will be found to be inadequate.

Since computing became commonplace, about a decade ago, almost every organizati seriously involved with computers has found reason to reexamine its situation. The questions posed often concerned cost, effectiveness, organizational arrangements and service modes. The questioners were, at least in the beginning, not disposed to wonder why they had to ask questions. Whey they became so disposed, they were often able to perceive a serious communication problem. The producers and users of computer service had very different backgrounds, imperatives and perspectives, and, as a consequence, were not speaking with one another with real effectiveness.

There are a number of measures which we believe should be considered by MCPS as means for improving the flow of information between DMICS and the community directly responsible for instruction. At the present time, the only "computer committee" seems to be a policy organization which meets very infrequently. It is suggested that a User's Committee should be formed, as a working organization competent to address and resolve real questions. Membership should include a senior person from DMICS, a policy person from the instructional sector and appropriate persons of departmental and divisional rank.

The Washington metropolitan area is the home of several individuals who are well qualified in the art and science of computing. Some few of these individuals having appropriate background, perspective, interest and sense of responsibility should be identified as members of an advisory board. In this capacity they would be expected to serve at regular working meetings, or site visits, and also to provide assistance in an ad hoc fashion.

As implied above, background and perspective are essential for the effective movement of information between the producer and user of computing. Aware of this fact, many institutions have lodged ultimate responsibility at a very senior level, e.g., at Stanford University, in the person of an Associate Provost having substantial credentials in technology and academic affairs. The MCPS may wish to consider the implications and possible benefits of an analogous arrangement.

- Dr. Gene Amdahl is one of the principle architects of System 360. A few years ago he left IBM to form his own computer company, competing with the top of line offerings of the major computer manufacturers. At a recent luncheon meeting in Washington, Dr. Amdahl described his reasons for leaving IBM -- he had investigated corporation policy for about a year and concluded that this policy was "good for IBM," but "not sufficiently parallel with the interests of the client." As evidence in support of his opinion, he has, working with meager resources, produced and marketed the Amdahl 470. This computer is precisely compatible with the 370/168, and it is smaller, significantly faster and significantly less expensive than the IBM equipment. There is not opportunity here to enlarge very much upon the lack of parallelism between computer marketing (not merely by IBM) and the interest of the user. Suffice it here to say, the client is confronted by secrecy, complexity, opacity and temptation -- a reason for very painstaking care in the selection of computer media.

- As indicated elsewhere in this report, there are a variety of means for the development and deployment of computing by MCPS, challenges and opportunities in need of further careful study. The present plans of the Department of Research and Evaluation to implement minicomputer service provide opportunity for the investigation of alternative uses of the technology. We feel that this is essential if there is to be further consistent progress.

BIBLIOGRAPHY

(1) An Introduction to the IBM 3270 Information Display System (1973). GA27-2739-4, File No. S360/S370/S3-09.

(2) BASSLER, RICHARD (1971). System Evaluation and Selection, A Bibliography. College Readings Incorporated.

(3) BAUER, WALTER F. (1962). Why multi-computers. Datamation, 8, No. 9.

(4) BENDER, VIRGINIA (1972). More mini power for management. Business Automation.

(5) BERNARDO, CHARLES M. (1976). Progress Report on the Department of Management Information and Computer Services. MCPS, Rockville, Md.

(6) BETZ, ROBERT E. (1974). Use of SMF data for performance analysis and resource accounting on IBM large-scale computers. NBS Special Publication 401, Computer Performance Evaluation.

(7) BROOKS, F.P., FERRELL, J.K., GALLIE, T.M. and PARKER, L.T. (1969). Introducing computing to smaller colleges and universities - a progress report. Communications of the ACM, 12.

(8) CADY, ROGER C. (1972). The Minicomputer - What Is It, Where Does It Fit in Distributive Systems. American Management Association Briefing Session #6377-01. Los Angeles, October 1972.

(9) Computer performance evaluation (1974). Proceedings of the Eighth Meeting of Computer Performance Evaluation Users Group. NBS Special Publication 401.

(10) DOLOTTA, T.A., BERNSTEIN, M.I., et al. (1976). Data Processing in 1980-1985. A Study of Potential Limitations to Progress. New York: John Wiley & Sons.

(11) FREEMAN, D.N. and PEARSON, R.R. (1968). Efficiency vs responsiveness in a multiple-service computer facility. Proceedings of the 1968 ACM Annual Conference. Association for Computing Machinery, New York.

(12) GILB, TOM. (1975). Laws of unreliability. Datamation, 21, No. 3.

(13) GRUENBERGER, FRED. (1969). Speaking of predictions. Datamation, 15, No. 10.

(14) HIRSCH, PAUL (1972). What's wrong with the in traffic control system? Datamation, 18, No. 8.

(15) HOBBS, L.C. and McLAUGHLIN, R.A. (1974). Minicomputer survey. Datamation, 20, No. 7.

(16) LAVER, F.J.M. (1969). User's influence on computer systems design. Datamation, 15, No. 10.

(17) LEVIN, K.D. and MORGAN, H.L. (1974). Optional Program and Data Locations in Computer Networks. Document: 74-10-01. University of Pennsylvania, Wharton School.

(18) LEVIN, K.D. (1974). Organizing Distributed Data Bases in Computer Networks. Document: 74-09-01. University of Pennsylvania, Wharton School.

(19) LITTRELL, R. FRED. (1974). Economies of scale in the IBM 360 and 370. Datamation, 20, No. 3.

(20) LITTRELL, R. FRED. (1972). The Costs of Computer Systems: Part 1: Economies of Scale in Hardware Systems for Commercial and Scientific Computing (unpublished).

(21) MATHEWS, VICTOR and POMERANTY, JOANNA V. (1975). Upgrading to a smaller machine. Datamation, 21, No. 5.

(22) McIVOR, R.A. (1974). Implementation of a Mini-Computer Based Information System. Part 1: System Overview. DSIS-TN-16-PT-1. Defense Scientific Information Service, Ottawa, Ont. (abstract in STAR 1301 (NASA)).

(23) MICHELS, JOHN. (1974). The mega-mini succeeds the Model T. Datamation, 20, No. 2.

(24) NIELSON, NORMAN R., WEEG, GERARD P., WEINGARTEN, FRED W. and WHITELEY, JAMES R. (1973). A Study of Regional Computer Networks. The University of Iowa.

(25) NORDLING, KARL I. (1971). Analysis of common carrier tariff rates. Datamation, 17, No. 9.

(26) PRICE, THOMAS G. (1974). Balanced Computer Systems. Document: SU-SEL-74-037, STAN-CS-74-435. Stanford University Electronics Laboratories.

(27) RILEY, WALLACE B. (1971). Minicomputer networks - a challenge to maxicomputers? Electronics Magazine, March 29, 1971.

(28) SKOVE, F.A. (1974). A Low Cost Minicomputer Data Base. Document: USNA-EPRD-5. United States Naval Academy, Environmental Protection Research and Development Team.

(29) SVOBODOVA, LILA (1974). Computer Performance Measurement and Evaluation Methods: Analysis and Applications. Document SU-SEL-74-036 TR-72. Stanford University Electronics Laboratories.

(30) TURNER, CHARLES W. (1974). NATIS - The case for distributed processing. Technical Memorandum Serial TM-60111. Program in Logistics, The George Washington University.

(31) WALKOWICZ, JOSEPHINE L. (1974). Benchmarking and workload definition: a selected bibliography with abstracts. NBS Special Publication 405.

(32) WEEG, GERARD P. (1974). Regional star networks as seen by the user. Networks for Research and Education. The MIT Press.

(33) WILLIAMS, LELAND H. (1972). A functioning computer network for higher education in North Carolina. Proceedings of 1972 Fall Joint Computer Conference, AFIPS Press.

(34) WLODARKIEWICZ, JAN. (1974). Reservation System Philosophy and Design Overview. Ramada Inns Project No. SD16A.